Production of 163Ho Radioisotope via Induced Nuclear Reaction by Proton and Deuteron: Comparison of Theoretical Calculation and Experimental Data

The main goal of the Electron Capture 163Ho (ECHO) project is to determine the mass of neutrino. In view of the ECHO experiment necessity of production of pure 163Ho source has been realized as it offers low Q value ~2.8 keV to the Electron Capture process. However, production of long lived (4570y) 163Ho radionuclides is a challenging task. Very few experimental data are exist in the literature, which could be used to decide which nuclear reactions can be used for production of 163Ho. The cyclotron based nuclear reactions are as follows: 163Dy(p,n)163Ho, 163Dy(d,2n)163Ho, 164Dy(p,2n)163Ho, natDy(α,xn)163Er→163Ho, 159Tb(7Li,3n)163Er→163Ho, 159Tb(7Li,p2n)163Ho and the 162Er(d,n)163Tm, 164Er(p,2n)163Tm. 163Tm decays to 163Ho through 163Er. The most potential nuclear reactions among them, are the (d,xn) and (p,xn). The excitation function of these reactions are collected and compared. Thick target yields were deduced for the main as well as the side reactions and the yields of the critical contaminating isotopes are discussed. Experiment The metal natDy foil was irradiated by proton beam up to 36 MeV energy and used a well-known “sandwich” foil technic for determination of cross section data. The general characteristics and procedures for irradiation, activity assessment and data evaluation (including estimation of uncertainties)were similar as in many of our earlier works [1]. The collected data is already published in [2]. Results The highest cross section and thick target yield can be reached using the (p,2n) reactions and enriched 164Dy target. Relevant data are collected in Table 1. The 164Dy(p,2n)163Ho reaction offers the best yield/price value, additionally the amount of potential contaminating stable and radioactive isotopes is the smallest (Table 2). Nuclear reaction Energy range [MeV] Activity [kBq] thickness [μm] price of target [kUSD] 163Dy(p,n)163Ho 6-14 614 471 1,2 163Dy(p,n)163Ho 2-20 875 1103 2,7 163Dy(d,2n)163Ho 4-20 3600 661 1,6 163Dy(d,2n)163Ho 4-30 5000 1350 3,3 164Dy(p,2n)163Ho 8,5-30 9800 2000 4,9 164Er(p,2n)163Tm 10,7-28,7 12000* 1620 61,9 Table 1, Thick target yields and prices of target materials (1800 h irradiation, 20 μA beam current) E-range [MeV] 157Tb [MBq] 158Tb [MBq] 159Dy [MBq] 163Ho [MBq] 5-11 0 0 0 0,20 5-18 3,81 0,04 968 1,74 5-28,7 18,27 1,10 20762 2,93 Table 2. Thick target yields of contaminating radio-isotopes and 163Ho (1800 h irradiation, 20 μA) The ECHO experiment requires a 163Ho radioisotope source with at least an amount of 1017 atoms, i.e. 1 MBq activity,. This activity can be produced by the proton irradiation with energy of 30 MeV and beam intensity of 20 μA during a week. Therefore the 164Dy(p,2n)163Ho reaction provides not only more “clean” source of 163Ho but financially is more effective than the reactor produced 163Ho. Experimental data of natDy(p,x)159,161, 162mHo reactions were compared with the theoretical calculation for production of 163Ho and showed a good agreement with them.